STUDY ON METALLIC ORE DEPOSITS OF CENTRAL-SOUTH REGION IN CHILE (チリ中南部地域の金属鉱床に関する研究)

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学位の種類	理学博士
学位記番号	理第766号
学位授与年月日	昭和59年11月28日
学位授与の要件	学位規則第5条第2項該当
最終学歴	西暦1967年12月 チリ大学数物科学科卒業
学位論文題目	STUDY ON METALLIC ORE DEPOSITS OF CENTRAL-SOUTH REGION IN CHILE (チリ中南部地域の金属鉱床に関する研究)
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論 文 内 容 要 旨

This research work is related with metallic ore deposits of central-south region of Chile, specially on massive sulfides of the Coastal Range. The boundary coordinates are 36°30′ and 40°00′ lat. S and 71°00′ and 73°40′ long. W. In this area two important mountain systems are distinguish : the Los Andes mountain range and the Coastal Range. The first one is characterized by the continuous presence, in time and space, of volcano-clastic and volcanic rocks from the Upper Cretaceous to the Quaternary. The oldest rocks encountered correspond to shales and fossiliferous marine sandstones and shales assigneed to the Dogger. The outcrops of these rocks are confined to a small zone in the southern part of the area under study and represent the only marine episode known in the evolution of the Andes mountain range of the region.

The Coastal Range is a massif formed of metamorphic and intrusive rocks assigned to the Middle and Upper Palezoic. Despite the modifications experiences by the rocks, due to the metamorphism and to the forces originated by the tectonic cycles of the Palezoic, Mesozic and Cainozoic (Hercynian and Andean Tectonic Cycles), it is possible to distinguish that the protolith is formed from a sequence of sedimentary rocks, possible marine, formed of graywackes, cherts, quartzites and shales. These rocks include intercalations with pillow-lavas.

Intrusive rocks are distributed in elongated bands in north-south direction, showing polarity in space and time. In this way, in the western part, corresponding to the Coastal Range, a batholith is recognized assigned to the Paleozoic ; towards the east, in the Andean sector, a granitoid crops out, probably Upper Cretaceous age, and finally, in the most eastern part there are stock type intrusives assigned to the Miocene on the basis to their field relations and isotopic determinations.

Two principal cycles of mineralization are recognized related to geologic phenomenon of the Paleozoic Tectonic Cycle and to processes related to the Andean Tectonic Cycle respectively. The massive sulfides of copper, zinc and iron (mainly chalcopyrite, sphalerite and pyite), chromite related to ultramafic serpentinized intrusions and stratabound deposits of manganese of the Coastal Range correspond to the Paleozoic System. The porphyry coppers, with molibdenum, are related to the Andean Tectonic Cycle, as are the systems of hydrothermal alteration which are known in the Andes mountain range. All are emplaced in granitic rocks of the Upper Cretaceous and the Middle Tertiary age. The principal deposits are Galletue, San Jose and Otue.

The gold deposits associated to breccia pipes with strong pyritization and silicification,

are also associated with the Andean Tectonic Cycle. The principal deposit of this type is *Minas del prado*. Other types of mineralization are veins of copper and veins of lead and zinc.

The porphyry copper lacks a zone of supergene enrichment due to the climatic and morphologic conditions which have affected the area, at least since the Upper Tertiary.

The massive sulfides of copper, zinc and iron of the Coastal Range are directly related to schists of quartz-chlorite-epidote-(albite-muscovite), denominated "green schists", whose protolith are volcanic and and volcano-clastic rocks deposited in marine environment. The chemical composition of the metavolcanic rocks permits associating them with tholeitic basalts.

The geologic antecedents obtained in this investigation permit explaining the formation of massive sulfides by means of a volcanic-exhalative process occurring in the ocean depths during the Paleozoic, similar to the hydrothermal systems actually recognized in the Galapagos Rift or the depositation of polymetallic sulfides coming from brines in the Red Sea.

Using the FeS contents in sphalerite as geobarometer, a minimum of 2. 3 kbar is obtained. Those values are interpretated as metamorphism pressure.

The filling temperature of fluid inclusions in quartz associated to sulfides varies between 310° and 360°C, and the sulfur fugacity change between -10.5 and -8.9.

Sulfur isotope composition shows and average of $+2.5$, this is near Besshi type isotope composition.

The geologic, mineralogic, and geochemical characteristics of the massive sulfides studied in the Coastal Range of the south of Chile permit concluding the following ;

- They are polymetallic deposits formed of copper, zinc and iron, without lead
- They are directly associated with volcano-clastic and volcanic metamorphozed rocks, of tholeiitic composition, with pillow structure, assigned to the Middle Paleozoic.
- The metavolcano-clastic and volcanic rocks are interlying in a sequence of schists of quartz-albite-muscovite-(chlorite), whose protolith would correspond to pelites and graywackes.

These characteristics indicate a depositing in the marine bottom, in which tholeiitic volcanism is developed ; the mineralizing solutions are directle related the volcanic systems.

By comparing the massive sulfides studied with those known in other parts of the world, includining the recent findings of the meso-oceanic mountain ranges and in the Red Sea, it

is possible to find genetic similarities not only with the Besshi deposits of Japan, but with the Cyprus type deposits and therefore, with the mineralization of the Galapagos Rift.

One is not prepared with arguments to prove the existence of a Paleozoic oceanic crust accreting on to the South American continent or the development of an arc-trench system associated with the paleo-zone of subduction, with magmatism of mafic to ultramafic type, with development of an volcanic-sedimentary marine sequence, and pillow lavas in the eugeosynclinal zone of the system.

On the other hand, the presence of a belt of ultramafic rocks serpentinized, with chromite (podiform bodies) is common in island-arc (for ex. Cuba, Philipines, etc,), even though it is not rare also encounter deposits, in the ocean crust, near the rift valleys. These bodies are represented in the area of the chilean massive sulfides of the Coastal Range.

The banded deposits of magnetite and hematite with quartzites that exist in the zone of Lago Lleu-Lleu (northern part of the Coastal Range under study) and those of manganese in Valdivia (southern part of the Coastal Range), would represent the distal and proximal phases respectively of the volcanic centers.

論文審査の結果の要旨

本論文は南米チリ中・南部地域における金属鉱床とくに塊状硫化物鉱床，クローム鉱床，鉄・マンガン鉱層及び斑岩銅鉱床などについて地質環況，火成活動と鉱化作用，鉱物共生などを詳らかにし，その資料から鉱床生成の機構とその条件，ひいてはその成因を明らかにしている。

本論文では本地域の鉱化作用を Paleozoic tectonic cycle に関係して生じたものと，Andes tectonic cycle に関係するものとに大別し，そのうち前者は Coastal Range にみられる塊状硫化物鉱床，クローム鉱床及び鉄・マンガン鉱層で，上部古生代の塩基性火成活動と密接な関係を有している。塊状硫化物鉱床は海底火山による熱水沈澱物で，一方クローム鉱床は正岩漿鉱床で，ともに塩基性または超塩基性火成活動による産物であり，これらの分布が空間的にその当時の plate の subduction zone と密接に関係していることを見出し，マグマの発生などその成因との関係を論じている。塊状硫化物鉱床は石英・緑泥石・緑れん石片岩(緑色片岩)中の層状鉱床で，黄鉄鉱・黄銅鉱・内亜鉛鉱・磁硫鉄鉱などよりなり，閃亜鉛鉱地質圧力計による圧力は2.3Kb，石英中の液体包有物充塡温度は310°～360°C，硫黄同位体比 $\delta^{34}S$(‰)は＋0.3～＋5.4，平均＋2.5で，本邦の別子型鉱床のそれと近い値をえている。

Andes tectonic cycle に関係して Andes Range に白亜紀乃至第三紀の花こう岩類の活動や熱水変質作用が行われ，斑岩銅鉱床を生成している。この鉱床は白亜紀トナーライト(85Ma)の活動末期の熱水溶液によって生じたもので，黄鉄鉱，黄銅鉱，輝水鉛鉱，磁硫鉄鉱，僅量の閃亜鉛鉱及び方鉛鉱を伴ない，そのうち黄銅鉱は熱水変質緑泥石帯及び石英・絹雲母帯，輝水鉛鉱は石英・絹雲母帯と密接な関係を有することを見い出している。チリの斑岩銅鉱床は世界的な規模を有し，銅資源としてきわめて重要であるが，その分布はチリ中・北部に限られ，これまで南部地域ではその存在が否定されていた。しかし，本研究によってチリ南部においても斑岩銅鉱床の存在が明らかにされ，この鉱化帯がチリ南部まで延びることを見い出した意義は大きい。またクローム鉱床もこれまでチリではその存在が全く考えられていなかったが，これまた新しい資料を提供している。

上記のように本論文はチリの金属鉱床について多くの新知見を与えており，本人が自立して研究活動を行なうに必要な高度の研究能力と学識を有することを示している。よって，Guillermo Alfaro Hanne 提出の論文は理学博士の学位論文として合格と認める。